May 1, 1998

Hydraulic Systems Hamonization Working Group Report- Task 2: Regulations

§ 25.1435 Hydraulic systems.

(a) Element design. Each element of the hydraulic system must be designed to:

(1) Withstand the proof pressure without permanent deformation that would prevent it from performing its intended functions, and the ultimate pressure without rupture. The proof and ultimate pressures are defined in terms of the design operating pressure (DOP) as follows:

Element	Proof(xDOP)	Ultimate(xDOP)
1. Tubes & fittings.	1.5	3.0
2. Pressure vessels containing gas		
High pressure (e.g., accumulators)	3.0	4.0
Low pressure (e.g., reservoirs)	1.5	3.0
3. Hoses	2.0	4.0
4. All other elements	1.5	2.0

(2) Withstand, without deformation that would prevent it from performing its intended functions, the design operating pressure in combination with limit structural loads that may be imposed;

(3) Withstand, without rupture, the design operating pressure multiplied by a factor of 1.5 in combination with ultimate structural load that can reasonably occur simultaneously;

(4) Withstand the fatigue effects of all cyclic pressures, including transients, and associated externally induced loads, taking into account the consequences of element failure; and

(5) Perform as intended under all environmental conditions for which the airplane is certificated.

(b) System design. Each hydraulic system must:

(1) Have means located at a flightcrew station to indicate appropriate system parameters, if

(i) It performs a function necessary for continued safe flight and landing; or

(ii) In the event of hydraulic system malfunction, corrective action by the crew to ensure continued safe flight and landing is necessary;

(2) Have means to ensure that system pressures, including transient pressures and pressures from fluid volumetric changes in elements that are likely to remain closed long enough for such changes to occur, are within the design capabilities of each element, such that they meet the requirements defined in § 25.1435(a)(1) through (a)(5);

(3) Have means to minimize the release of harmful or hazardous concentrations of hydraulic fluid or vapors into the crew and passenger compartments during flight;

(4) Meet the applicable requirements of §§ 25.863, 25.1183, 25.1185, and 25.1189 if a flammable hydraulic fluid is used; and

(5) Be designed to use any suitable hydraulic fluid specified by the airplane manufacturer, which must be identified by appropriate markings as required by § 25.1541.

(c) Tests. Tests must be conducted on the hydraulic system(s), and/or subsystem(s) and elements, except that analysis may be used in place of or to supplement testing, where the analysis is shown to be reliable and appropriate. All internal and external influences must be taken into account to an extent necessary to evaluate their effects, and to assure reliable system and element functioning and integration. Failure or unacceptable deficiency of an element or system must be corrected and be sufficiently retested, where necessary.

(1) The system(s), subsystem(s), or element(s) must be subjected to performance, fatigue, and endurance tests representative of airplane ground and flight operations.

(2) The complete system must be tested to determine proper functional performance and relation to the other systems, including simulation of relevant failure conditions, and to support or validate element design.

(3) The complete hydraulic system(s) must be functionally tested on the airplane in normal operation over the range of motion of all associated user systems. The test must be conducted at the system relief pressure or 1.25 times the DOP if a system pressure relief device is not part of the system design. Clearances between hydraulic system elements and other systems or structural elements must remain adequate and there must be no detrimental effects.

f:\home\mwahi\arac1435\task2reg.doc
Revised on May 1, 1998, based on telecon with Jim draxler.

May 4, 1998
Hydraulic Systems Harmonization Working Group Report - Task 2: Advisory Circular AC 25.1435-1

HYDRAULIC SYSTEM CERTIFICATION
TESTS, AND ANALYSIS

1. PURPOSE. This Advisory Circular (AC) provides guidance material for use as an acceptable means, but not the only means, of demonstrating compliance with the requirements of § 25.1435 and other sections of the Federal Aviation Regulations (FAR) that contain hydraulic system requirements. It is not mandatory and does not constitute a regulation.

2. RELATED DOCUMENTS. Section 25.1435 of the FAR, as amended through Amendment 25-xx, and other sections relating to hydraulic installations.

a. Related Federal Aviation Regulations. Sections which contain requirements for the design, substantiation and certification of hydraulic systems include:

§ 25.301	Loads
§ 25.303	Factor of safety.
§ 25.863	Flammable fluid fire protection.
§ 25.1183	Flammable fluid-carrying components.
§ 25.1185	Flammable fluids.
§ 25.1189	Shutoff means.
§ 25.1301	Function and installation.
§ 25.1309	Equipment, systems and installations.
§ 25.1322	Warning, caution and advisory lights.
§ 25.1541	Markings and Placards

Additional part 25 sections (and their associated advisory circulars where applicable) that can have a significant impact on the overall design and configuration of hydraulic systems are, but are not limited to:

§ 25.671	General: Control systems
§ 25.729	Retracting mechanism
§ 25.903	Engines
§ 25.943	Negative acceleration (JAR 25x1315)

b. Advisory Circulars (AC's).

AC 25.1309-1A	System Design and Analysis
AC 120-42	Extended Range Operation with Two Engine Airplanes

AC 20-128	Design Considerations for Minimizing Hazards Caused by Uncontained Turbine Engine and Auxiliary Power Unit Rotor and Fan Blade Failures

c. Technical Standard Orders (TSO's).

TSO-C47	Pressure Instruments-Fuel, Oil, and Hydraulic
TSO-C75	Hydraulic Hose Assemblies (JTSO-2C75)

Advisory Circulars and Technical Standard Orders can be obtained from the U.S. Department of Transportation, Subsequent Distribution Office, SVC-121.23, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20785.

d. Society of Automotive Engineers (SAE) Documents.

ARP 4752	Aerospace - Design and Installation of Commercial Transport Aircraft Hydraulic Systems
ISO 7137	Environmental Conditions and Test Procedures for Airborne Equipment (not an SAE document but is available from the SAE)

These documents can be obtained from the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, Pennsylvania, 15096.

e. Military Documents.

MIL-STD-810	Environmental Test Methods and Engineering Guidelines

These documents can be obtained from Department of Defense, Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.

3. BACKGROUND. Effective February 1, 1965, part 25 was added to the FAR to replace Part 4b of the Civil Air Regulations (CAR). For hydraulic systems, CAR 4b.653, 4b.654 and 4b.655 respectively became §§ 25.1435(a), 1435(b) and 1435(c) of the FAR. Since then § 25.1435 has been revised under Amendment 25-13 (1967), Amendment 25-23 (1970), Amendment 25-41 (1977), Amendment 25-72 (1990), and Amendment 25-XX (1996), to make the regulations more comprehensive and to delete redundancies.

In Europe, the Joint Aviation Requirements (JAR) -25 were developed by the Joint Aviation Authorities (JAA) to provide a common set of airworthiness standards for use within the European aviation community. The airworthiness standards for European type certification of transport category airplanes, JAR-25, are based on part 25 of the FAR.

Although part 25 and JAR-25 are very similar, they are not identical. Differences between the FAR and the JAR can result in substantial additional costs when airplanes are type certificated to both standards. These additional costs, however, frequently do not bring about an increase in safety. For example, part 25 and JAR-25 may use different means to accomplish the same safety intent. In this case, the manufacturer is usually burdened with meeting both requirements, although the level of safety is not increased correspondingly. Recognizing that a common set of standards would not only economically benefit the aviation industry, but would also maintain the necessary high level of safety, the FAA and JAA consider harmonization to be a high priority.

In 1992, the harmonization effort was undertaken by the Aviation Rulemaking Advisory Committee (ARAC). A working group of industry and government hydraulic systems specialists of Europe, Canada, and the United States was chartered by notice in the Federal Register (57 FR 58843, December 12, 1992). The working group was tasked to develop harmonized standards and any collateral documents, such as advisory circulars, concerning new or revised requirements for hydraulic systems, and the associated test conditions for hydraulic systems, installed in transport category airplanes (§ 25.1435).

The advisory material contained in this circular was developed by the Hydraulic Systems Harmonization Working Group to ensure consistent application of the revised standards.

4. DISCUSSION.

a. Element Design.

(1) (Ref. § 25.1435(a)(1))

The design operating pressure (DOP) is the normal maximum steady pressure. Excluded are reasonable tolerances, and transient pressure effects such as may arise from acceptable pump ripple or reactions to system functioning or demands that may affect fatigue. Fatigue is addressed in paragraph (a)(4) of this section.

The DOP for low pressure elements (e.g., return, case-drain, suction, reservoirs, etc.) is the maximum pressure expected to occur during normal user system operating modes. Included are transient pressures that may occur during separate or simultaneous operation of user systems such as slats, flaps, landing gears, thrust reversers, flight controls, power transfer units, etc. Short term transient pressures, commonly referred to as pressure spikes, that may occur during

the selection and operation of user systems (e.g., those pressure transients due to the opening and closing of selector/control valves, etc.) may be excluded, provided the fatigue effect of such transients is addressed in accordance with paragraph (a)(4) of this section.

In local areas of systems and elements, the DOP may be different from the above due to the range of normally anticipated airplane operational, dynamic, and environmental conditions. Such differences should be taken into account.

At proof pressure, seal leakage not exceeding the allowed maximum in-service leak rate is permitted. Each element should be able to perform its intended functions when the DOP is restored.

For (a)(1), (a)(2), and (a)(3), the pressure and structural loads, as applicable, should be sustained for sufficient time to enable adequate determination that compliance is demonstrated. Typically a time of 2 minutes for proof conditions and 1 minute for ultimate condition will be considered acceptable.

The term 'pressure vessels' is not intended to include small volume elements such as lines, fittings, gauges, etc. It may be necessary to use special factors for elements fabricated from non-metallic/composite materials.

(2) (Ref. § 25.1435(a)(2)) Limit structural loads are defined in § 25.301(a). The loading conditions of 14 CFR, part 25, subpart C to be considered include, but are not limited to, flight and ground maneuvers, and gust and turbulence conditions. The loads arising in these conditions should be combined with the maximum hydraulic pressures, including transients, that could occur simultaneously. Where appropriate, thermal effects should also be accounted for in the strength justification. For hydraulic actuators equipped with hydraulic or mechanical locking features, such as flight control actuators and power steering actuators, the actuators and other loaded elements should be designed for the most severe combination of internal and external loads that may occur in use. For hydraulic actuators that are free to move with external loads, i.e., do not have locking features, the structural loads are the same as the loads produced by the hydraulic actuators. At limit load, seal leakage not exceeding the allowed maximum in-service rate is permitted.

(3) (Ref. § 25.1435(a)(3)) For compliance, the combined effects of the ultimate structural load(s) as defined in §§ 25.301 and 25.303 and the DOP, which can reasonably occur simultaneously, should be taken into account with a factor of 1.5 applied to the DOP. In this case the overall structural integrity of the element should be maintained. However, it may be permissible for this element to suffer leakage, permanent deformation, operational/functional failure or any combination of these conditions. Where appropriate, thermal effects should also be accounted for in the strength justification.

(4) (Ref. § 25.1435(a)(4)) Fatigue, the repeated load cycles of an element, is a significant contributor to element failure. Hydraulic elements are mainly subjected to pressure loads, but may also see externally induced load cycles (e.g. structural, thermal, etc.). The applicant should define the load cycles for each element. The number of load cycles should be evaluated to produce equivalent fatigue damage encountered during the life of the aircraft or to support the assumptions used in demonstrating compliance with § 25.1309 . For example, if the failure analysis of the system allows that an element failure may occur at 25% of aircraft life, the element fatigue life should at least support this assumption.

(5) (Ref. 25.1435(a)(5)) Airplane environmental conditions that an element should be designed for are those under which proper function is required. They may include, but are not limited to: temperature, humidity, vibration, acceleration forces, icing, ambient pressure, electromagnetic effects, salt spray, cleaning agents, galvanic, sand, dust, and fungus. They may be location specific (e.g., in pressurized cabin vs. in unpressurized area) or general (attitude). For further guidance on environmental testing, suitable references include, but are not limited to: Military Standard, MIL-STD-810 "Environmental Test Methods and Engineering Guidelines", ED-14/RTCA Document No. DO-160 (Environmental Conditions and Test Procedures for Airborne Equipment) as referenced in advisory circular No. AC 21-16, and International Organization for Standardization Document No. ISO 7137-Environmental Conditions and Test Procedures for Airborne Equipment.

b. System Design. (Ref. 25.1435(b)) Design features that should be considered for the elimination of undesirable conditions and effects are: (a) Design and install hydraulic pumps such that loss of fluid to or from the pump cannot lead to events that create a hazard that might prevent continued safe operation. For example, engine driven pump shaft seal failure or leakage, in combination with a blocked fluid drain, resulting in engine gear box contamination with hydraulic fluid and subsequent engine failure. (b) Design the system to avoid hazards arising from the effects of abnormally high temperatures which may occur in the system under fault conditions.

(1) (Ref. 25.1435(b)(1)) Appropriate system parameters may include, but are not limited to, pump or system temperatures and pressures, system fluid quantities, and any other parameters which give the pilot indication of the functional level of the hydraulic systems.

(2) (Ref. 25.1435(b)(2)) Compliance may be shown by designing the systems and elements to sustain the transients without damage or failure, or by providing dampers, pressure relief devices, etc.

(3) (Ref. 25.1435(b)(3)) Harmful or hazardous fluid or vapor concentrations are those that can cause short term incapacitation of the flight crew or long term health effects to the passengers or crew. Compliance may be shown by taking design precautions, to minimize the likelihood of releases and, in the event of a release to minimize the concentrations. Suitable precautions, based on good engineering judgment, include separation of air conditioning and hydraulic

May 4, 1998

Hydraulic Systems Harmonization Working Group Report - TASK 2 - Disposition of Comments - Notice 96-6 and advisory Circular 25.1435-1

Background

Eight commenters responded to the request for comments contained in NPRM 96-6, the notice of availability for AC 25.1435-1 and the corresponding JAA document NPA 25F-273 including AMJ 25.1435. Comments were received from foreign airplane manufacturers, foreign airworthiness authorities, and both foreign and domestic industry organizations. The majority of the commenters agreed with the proposal and recommended its adoption. However, some commenters disagreed with the proposal while providing alternative proposals that appeared to merit further consideration by the ARAC. Therefore the FAA, as requested by the JAA tasked the ARAC Hydraulic Systems Harmonization Working Group (HWG) by notice in the Federal Register (62 FR 38187, July 16, 1997) to consider the comments and provide recommendations for the disposition of the comments along with any recommendations for changes to the proposal. The disposition of the comments that follows is based on the agreement reached by the HWG.

Disposition of comments

Proposal 1, § 25.1435(a)(1). One commenter stated that the structure of the punctuation in the first sentence appears to allow leakage under proof pressure, providing that such leakage does not prevent the element from performing its intended function. The proper intent should be to prohibit any leakage under proof pressure. The commenter suggested to revise the regulatory text of the first sentence as follows: "(1) Withstand the proof pressure without leakage and without permanent deformation that would prevent it from performing its intended function, and withstand the ultimate pressure without rupture."

The HWG agrees that some clarification of the rule text is necessary. The HWG does not however agree with the commenter's suggested text because under proof pressure, some external seal leakage is allowed as long as the element's ability to perform its intended function remains unaffected once the DOP is restored. Accordingly, the final rule text of the first sentence and the associated advisory have been revised to read:

Rule text: (a) Element design. Each element.....

(1) Withstand the proof pressure without permanent deformation that would prevent it from performing its intended functions, and the ultimate pressure without rupture.

Advisory text: The following text has been added under section 4.a(1), Ref. 25.1435(a)(1) of the companion advisory circular:

At proof pressure, seal leakage not exceeding the allowed maximum in-service leak rate is permitted. Each element should be able to perform its intended functions when the DOP is restored." For consistency, under 4.a(2), Ref. 25.1435(a)(2) of the advisory circular, the following text will be added: "At limit load, seal leakage not exceeding the allowed maximum in-service leak rate is permitted."

Another commenter recommended that consideration be given to address system "return pressures" in addition to the "design, proof, and ultimate pressures" in the table presented as part of § 25.1435(a)(1). The Harmonization Working Group (HWG) does not see the need for adopting the suggestions because the regulation was written in such a form as to make it unnecessary to differentiate between high/supply pressure and low/return pressure in applying factors specified in the table.

A third commenter recommended that the advisory material should include guidance for determination of the design operating pressure (DOP) for elements in the low pressure side of the system. The HWG concurs and has added the following

definition in the advisory circular section 4.a(1), Ref. 25.1435(a)(1): "The DOP for low pressure elements (e.g., return, case-drain, suction, reservoirs, etc.) is the maximum pressure expected to occur during normal user system operating modes. Included are transient pressures that may occur during separate or simultaneous operation of user systems such as slats, flaps, landing gears, thrust reversers, flight controls, power transfer units, etc. Short term transient pressures, commonly referred to as pressure spikes, that may occur during the selection and operation of user systems (e.g., those pressure transients due to the opening and closing of selector/control valves, etc.) may be excluded, provided the fatigue effect of such transients is addressed in accordance with paragraph (a)(4) of this section".

A fourth commenter proposed to replace the term DOP with the term "nominal pressure" claiming that this terminology was consistent with MIL-standards and the commenter's own country's practices where operating pressure of 3000 psi corresponds to the nominal pressure. The HWG notes that consideration was given by the working group to use the term "nominal pressure" but no agreement could be reached on its definition because the term "nominal" could involve tolerances, fluctuations, and other interpretations; the term "DOP" is more specific. This commenter also proposed that the same safety factor be used for all elements e.g. not less than 1.5 for proof pressure and not less than 3.0 for burst pressure. The HWG does not agree. Existing U.S. and European industry standards/practices were used to arrive at these factors and to harmonize with current JAR 25, Appendix "J" (Appendix "K" effective May 27, 1994) requirements. The commenter's suggestion would simplify the requirements but does not reflect the acceptable industry standards. For the above reasons, the proposed

§ 25.1435(a)(1) has been modified by deleting reference to "without leakage" and text added in the advisory circular regarding allowed leakage and a definition of the DOP for elements in the low pressure side of the system.

Proposals 2 and 3, §§ 25.1435(a)(2), (3). One commenter stated that in spite of the guidance material, there is still room for misunderstanding the meaning of structural loads in the context of hydraulic system elements. The intent is that the designer must consider those loads arising when the aircraft responds to the relevant critical loading conditions of subpart C, in which case it would improve clarity to say so. Also, the strength analysis of hydraulic system elements must not stop at consideration of inertia, dynamic and aerodynamic loads, but must also include consideration of strains imposed by the deformation (bending, twist, etc.) of the structure to which the elements are attached. Furthermore, thermal stresses are likely to be important at the normal operating temperature of the hydraulic system. To address these factors, the following amendment is proposed:

§ 25.1435(a)(2) - Withstand, without deformation that would prevent it from performing its intended functions, the design operating pressure in combination with the loads and structural deflections arising from the critical limit loading conditions of subpart C. Where appropriate, thermal effects must also be taken into account.

§ 25.1435(a)(3) - Withstand, without rupture, the design operating pressure multiplied by a factor of 1.5, in combination with the ultimate loads and ultimate structural deflections arising from the critical loading conditions of subpart C. Where appropriate, thermal effects must also be taken into account.

The commenter also suggested that the advisory circular section 4(a)(2), third sentence be modified to read "The loading conditions to be considered include, but are not limited to flight and ground maneuvers, and gust and turbulence conditions, The

loads arising in these conditions should be combined with the maximum hydraulic pressures, including dynamic transients, that could occur simultaneously. Where appropriate, thermal effects should also be accounted for in the strength justification".

The HWG accepts these comments. However, following discussions we have determined that it would be more appropriate that the texts for §§ 25.1435(a)(2) and (a)(3) should remain as proposed in the NPRM but that the associated advisory material should be improved, as suggested by the commenter, to more adequately reflect the intent of the proposed requirements. The advisory circular text, section 4.a(2) is therefore amended to read as follows:

(2) (Ref. § 25.1435(a)(2)) Limit structural loads are defined in § 25.301(a). The loading conditions of subpart C to be considered include, but are not limited to flight and ground maneuvers, and gust and turbulence conditions. The loads arising in these conditions should be combined with the maximum hydraulic pressures, including transients, that could occur simultaneously. Where appropriate, thermal effects should also be accounted for in the strength justification. For hydraulic actuators equipped with hydraulic or mechanical locking features, such as flight control actuators and power steering actuators, the actuators and other loaded elements should be designed for the most severe combination of internal and external loads that may occur in use. For hydraulic actuators that are free to move with external loads, i.e., do not have locking features, the structural loads are the same as those produced by the hydraulic actuators. At limit load, seal leakage not exceeding the allowed maximum in-service leak rate is permitted. For consistency, the statement "Where appropriate, thermal effects should be accounted for in the strength justification" will also be added at the end of advisory circular section 4.a(3).

The same commenter further added "The final sentence in section 4.a(3) of the advisory circular specifically allows operational/functional failure under ultimate load conditions. However, the use of the word "under" in this context could give rise to confusion as to whether operational/functional failure is allowed "below" ultimate load. If so, this would be inconsistent with the safety objectives set by the structural requirements that prohibit failure at any load level up to and including ultimate. If a hydraulic component is essential for continued safe flight then it must not be allowed to fail, or lose operational functionality, at or below, ultimate load conditions. For example, the hydraulic system powering an elevator would be critical for recovery from the design maneuvering condition, and must not be allowed to fail below the ultimate loads associated with this condition. To improve clarity and remove confusion, the wording should be changed to state positively that operational/functional failure is not allowed at any load level up to and including ultimate." The HWG agrees with the commenter that no structural failure may occur up to ultimate load. However, we do not require hydraulic components to remain functional beyond limit load. Therefore, no change is necessary.

Another commenter suggested that time limits for proof and burst pressure tests be included in the regulation, not just in the advisory circular. The HWG does not agree. The recommended time limits in the advisory circular are the acceptable industry standards/practices and have proven to be adequate for safety. Including them in the regulations does not add anything to the safety. The commenter also stated that the definitions of pressures and/or pressures and times given in the advisory circular do not appear to match the current JAA criteria and wondered whether they had been fully harmonized. The HWG notes that the proposed pressures and times have been fully harmonized although they may differ from the current JAA criteria (Appendix J to JAR 25). The regulatory agencies have agreed to use the new criteria.

A third commenter stated that the advisory material for § 25.1435(a)(3) was simply rephrasing of the regulation and not a means of compliance as expected; a more detailed clarification in the AC of the methods of implementing this requirement was desirable. The HWG notes that the first statement in the AC references regulations relevant to the requirement, however the second statement is advisory and gives details of the methods of pass/fail of a test of the requirement but allows flexibility for the applicant to propose any method acceptable to the authority. In light of the above discussion, §§ 25.1435(a)(2) and (a)(3) are adopted as proposed with clarifying text added in the advisory circular to account for thermal effects in strength justification and to allow some leakage at limit load.

Proposal 4, § 25.1435(a)(4). One commenter stated that in order to provide sufficient safeguard against the possibility of a premature failure in the operational life of an airplane, it will be necessary to consider the effects of material fatigue variability on life. Conventionally, this would be done through application of an appropriate scatter factor to the result of the fatigue analysis or fatigue test (See ACJ 25.571(a)(3)). To ensure that the effects of variability are properly taken into account in the interpretation of the fatigue analysis and test data required by this paragraph, the following amendment is proposed:

§ 25.1435(a)(4) - Withstand, without failure, the fatigue effects of repeated loads of variable magnitude expected during its service life, including pressure cycles, pressure transients, externally induced loads, structural deformations and, where appropriate, thermal effects. Appropriate safe-life scatter factors must be applied.

The HWG understands the concerns expressed here, but does not agree with the linkage to § 25.571. However, the intent of this comment is already addressed in AC section 4.c(1), Ref. § 25.1435(c)(1).

The same commenter added "The term "cyclical loads" in advisory circular section 4.a(4) is usually associated with a periodic force. It would be better to use the term "load cycles". This paragraph would be an appropriate place to give guidance on the need to cover scatter in fatigue properties - ACJ 25.571(a) has some relevant guidance material". The HWG agrees with the use of the term "load cycles" and the advisory text has been modified accordingly. The HWG does not agree that any advisory is needed for scatter factors or the relevance to § 25.571.

Another commenter stated that it is not understood how the current JAR 25.1435(a)(6) requirement - means of providing flexibility - comes into the new § 25.1435(a)(4) requirement. The HWG notes that it is not the new § 25.1435(a)(4) but rather the new § 25.1435(a)(5) that addresses the current JAR 25.1435(a)(6) requirement and proposal 5 clearly states that. The new § 25.1435(a)(5) addresses the environmental factors, including the vibrational & acceleration effects of the elemental installation as discussed in the associated advisory material. The commenter also suggested including in the advisory material, a recommendation for the scatter factor to be used when conducting the fatigue testing (for example 4.0 for non-critical parts, 6.0 for critical parts). The HWG notes that as stated under section 4.c(1) in the advisory circular, the manufacturer may select design factors identified in accepted manufacturing, national, military, or industry standards provided that it can be established that they are suitable for the intended application. It is not the intent of the regulations to supersede or conflict with what is established by existing industry standards.

This same commenter also wondered whether there should be an allowance for the fact that a component might be fitted on more than one aircraft in its lifetime, and hence the fatigue cycles could well be considerably more than predicted for a part which is assumed to be on the aircraft for its entire life; it would be very useful to have a

consistent policy for this issue. The HWG notes that the requirements of §§ 25.671 and 25.1309 specify that the failure of no single element shall jeopardize the continued safe flight and landing of the aircraft. Section 25.1435(a)(4) specifies the design requirements of the element and its failure consequences should be understood and addressed by the designer. The existing requirements adequately cover the overall safety of an aircraft and this requirement (or CFR 14 part 25) does not deal with parts tracking.

Yet another commenter suggested that Society of Automotive Engineers (SAE) document ARP 1383 "Impulse Testing of Hydraulic Actuators, Valves, Pressure Containers, and Similar Fluid System Components" be included as a reference in the AC. The HWG notes that ARP 4752 "Aerospace-Design and Installation of Commercial Transport Aircraft Hydraulic Systems" listed in the advisory circular in turn refers to ARP 1383. All of the relevant SAE documents are referenced in ARP 4752 and are too numerous to be individually listed in the AC. For the reasons stated, § 25.1435(a)(4) is adopted as proposed.

Proposal 5, § 25.1435(a)(5). One commenter recommended that the advisory material state that thermal effects be particularly considered for accumulators which are isolated from the hydraulic system by non-return valves. The HWG notes that § 25.1435(a)(5) addresses the environmental factors that are to be considered when designing the element and that in the AC, temperature effects are specifically stated as one of the variables to be addressed. For the stated reasons, § 25.1435(a)(5) is adopted as proposed.

Proposal 6, § 25.1435(b)(1) One commenter expressed a concern that the requirements of (b)(1)(i) could be open for interpretation by different airworthiness authorities, particularly with respect to fluid level quantity indication. The commenter further stated

that there were occasions when the warning/indication philosophy that had been agreed to with one airworthiness authority had not been agreed to by other authorities and this therefore led to redesign and/or other additional costs. The HWG notes that the commenter's concern of eliminating differences in interpretations is the basic reason for harmonization effort. The intent of the harmonized rule is to specify what type of indication is required from the point of view of what the pilot can use, without specifying the design of the indication.

Another commenter stated that moving from prescriptive to general indication requirements is considered to be sensible, but to be truly meaningful, the requirement should be stated more objectively. Paragraph (b)(1)(ii) is close to being an objective requirement but (b)(1)(i) is not. In fact it is not apparent what indication might be required by (b)(1)(i) that would not be required by (b)(1)(ii). The HWG does not agree. By making the changes to the existing requirement of JAR 25.1435(a)(2), which refers to the provision of indications of system pressure and fluid quantity, to one which is less prescriptive in that it requires the provision of indications of only the appropriate parameters is an objective statement of the requirement. The HWG has determined that, to ensure continued safe flight and landing, each hydraulic system that either (i) performs an essential function or (ii) that requires corrective action by the flight crew following a malfunction (irrespective of whether it performs an essential function) must be associated with the appropriate flight crew indications. The associated advisory material clarifies that the "appropriate indications" are not limited other than that they should be appropriate.

The second commenter also pointed out that in the advisory circular section 4.b, the statement "These requirements are unique to hydraulic systems is questioned. Surely, the intent of § 25.1435(b)(1) is not". The HWG agrees with the commenter.

Accordingly, the first sentence "These requirements are unique to hydraulic systems, and may compliment § 25.1309" has been deleted and the second sentence has been modified to read "Design features that should be considered for elimination of undesirable conditions and effects are:

The first commenter also pointed out that the NPRM cited this requirement as § 25.1435(a)(1) when it should have been § 25.1435(b)(1). The HWG concurs that the preamble of the proposed rule had a typographical error but not the proposed rule text. For the stated reasons, § 25.1435(b)(1) is adopted as proposed with clarifying changes made in the advisory circular text including deleting reference to § 25.1309.

Proposals 7, 8, and 9, §§ 25.1435(b)(2), (3), and (4) No comments were received. §§ 25.1435(b)(2), (3), and (4) are therefore adopted as proposed.

Proposal 10, § 25.1435(b)(5). One commenter stated that the means to identify the hydraulic fluid may not always be practical - particularly for small components such as in line non-return valves. The HWG notes that the intent of the requirement is not that every component be so identified but rather that suitable placarding be provided as practical so that servicing of the hydraulic system(s) is done with the specified fluid. As pointed out by another commenter, typical/acceptable marking locations for the hydraulic fluid used are hydraulic actuators, refill points, reservoirs, and applicable servicing documents. The second commenter recommended specifying these typical locations in the AC. The HWG notes that specifying locations could be interpreted as excluding other acceptable locations or mandating certain locations.

A third commenter suggested that FAA consider clarifying the language in proposed paragraph 25.1435(b)(5) to address the situation of fluid mixtures. The HWG

infers that the commenter is referring to the advisory circular paragraph (b)(5) which states: "If more than one approved fluid is specified, the term suitable hydraulic fluid is intended to include acceptable mixtures". The HWG notes that acceptable fluids and/or mixtures are those listed in the airplane manufacturer's maintenance manuals as approved for that airplane model. For the stated reasons, § 25.1435(b)(5) is adopted as proposed.

Proposal 11, § 25.1435(c). One commenter stated that as written, this section continues the practice of including some means of compliance within the main code rather than in the advisory material. Section 25.1309(d) currently contains the same anomaly, but it is understood that the decision has been taken in the § 25.1309 Working Group to rectify this by moving § 25.1309(d) into the advisory material. It is recommended that the same thing could be done here. The HWG partially accepts this comment, and proposes to amend the opening paragraph by deleting the words "To demonstrate compliance with § 25.1435 and support compliance with § 25.1309". The paragraph would commence "Tests must be conducted...." and would otherwise remain unchanged from the original proposal. Except for qualifying statements that bring immediate clarification to the primary regulatory statements, the remainder of the paragraph is considered regulatory and not advisory. Section 25.1435(c) has been revised accordingly.

Proposal 11, §§ 25.1435(c)(1) and (c)(2). One commenter stated "Although it is considered that an endurance test of a complete aircraft hydraulic system is a very useful test, there are circumstances where a full endurance test is an expensive exercise with no benefit to the integrity and safety of the aircraft. Particular examples of this are:

a) The aircraft hydraulic system is substantially based on an existing, well proven in-service aircraft,

b) The number and/or nature of services which are powered hydraulically are such that the loss of the system has no significant effect on the airworthiness of the aircraft."

The HWG concurs with the commenter in that testing may not always be necessary and the proposed requirement test criteria already include the provision "except that analysis may be used in place of or to supplement testing, where the analysis is shown to be reliable and appropriate." The type and extent of testing guidance covered in AC adequately address commenter's concern. In addition, full system testing is not required, subsystem or element testing is allowed. The commenter further states that they believe some engineers quite often think of endurance as fatigue testing. They therefore recommended that "pressure impulse" be added after fatigue in this section." The HWG notes that section 4.c(1) in the advisory circular adequately defines these terms and the associated testing. For the stated reasons, §§ 25.1435(c)(1), and (c)(2) are adopted as proposed.

Proposal 12, § 25.1435(c)(3). One commenter stated: "It is proposed that this requirement be dispensed with. This is because

a) In the course of an aircraft production run, the hydraulic system can undergo many modifications (including the introduction of a cargo door system) which affect the system installation. Yet, it is the norm that this is a once only test which is conducted on an early production aircraft during the certification test programme.

b) Each aircraft should be inspected with respect to clearances with the hydraulic system unpressurised and then pressurised. It is doubtful whether there will be any significant movement of the piping, hoses, components, etc as a result of increasing the pressure by 25%."

The HWG notes that this test is conducted only once per installation. However, the FAA requires that any significant modification(s) such as introduction of a cargo door system, a ram air turbine (RAT), or a tail-skid system be assessed along with any associated/affected system(s) to meet this requirement. There are several recent examples of such modifications that required additional testing. Such testing may also be supplemented by analysis if appropriate.

Regarding the commenter's statement about insignificant movement of the piping etc. when pressurized at 25% above nominal, the HWG concurs and has therefore proposed that instead a full range-of-motion testing be conducted at just below the system relief pressure setting. The commenter goes on to state "There are some reservations with the new test proposal, as follows:

a) The requirement to check clearances may not be easily achieved for those parts of the system which are actuated, for example, landing gear, flight controls.

b) As the system is pressurised to a higher value, there may be concerns about safety, particularly as the services may operate quicker.

c) The validity of the test results could be queried as the flight control actuators are unloaded."

The HWG notes that : a) Section 4.c(3) of the advisory circular adequately addresses this concern by stating: "it may be permissible that certain components of the system need not be tested if it can be shown that they do not constitute a significant part of the system with respect to the evaluation of adequate clearances or detrimental effects".

b) The system(s) relief valve(s) protect against over-pressurization. Standard safety precautions on the factory floor while the testing is being conducted must be

practiced. There are no appreciable differences from full functional test(s) conducted by the manufacturer.

c) The intent is not to check/verify structural deflections or motion of surfaces for flight controls. Loading is not anticipated to cause surface deflections.

Lastly, the commenter states: "With respect to the low pressure side of the hydraulic system, it is proposed that the tests be conducted with a dummy return filter element installed, thereby forcing all the fluid through the return filter bypass. This meets the same criteria as for increasing the system pressure to 125%, that is increasing the pressure levels to that which could conceivably occur in service."

The HWG notes that the commenter's scenario may be applicable to some of the hydraulic system architectures (layouts), but not all. It is the FAA's policy to allow flexibility for the applicant to propose a method of compliance which is acceptable to the cognizant certification office. In light of the discussion above and the explanations already provided in the advisory material, § 25.1435(c)(3) is adopted as proposed.

General: One commenter stated: "It is considered that the harmonization of the FAR/JAR 25.1435 has produced a good set of airworthiness requirements. However, there is still a concern that there are areas within the new requirements which could be subject to interpretation by airworthiness surveyors. It is recommended that the FAA/JAA review the advisory material and ensure that there are no areas where misinterpretation can occur. The reason for this comment is not to direct concern at the professionalism of the JAA and FAA, but rather there is a concern that other national authorities could read in additional requirements where none were intended." The HWG together reviewed and developed these regulations and the associated advisory material. Both the regulations and the advisory material are fully harmonized. A considerable amount of time was spent discussing the very issues and concerns raised by the

commenter to arrive at the final rule and the AC. Where practicable the HWG have written the regulations to allow design, test, and analysis flexibility in means of compliance.

Another commenter pointed out that the word "must" in advisory circular sections 4(a)(1), (a)(2), and (a)(4), and the word "shall" in section (a)(3) should be replaced by "should". The HWG agrees and the text in the AC has been revised. The commenter added that in section 4(a)(1), third paragraph, reference to "structural loads" should be replaced by "external loads". The HWG does not agree since reference to structural loads is appropriate as used in §§ 25.301 and 25.1435(a)(1).

With the exception of the changes noted in §§ 25.1435(a)(1) and (c), this final rule is adopted as proposed in Notice 96-6.

f:\home\mwahi\arac1435\rulehyd4.doc

Revised on October 30, 1997 based on HWG agreement reached at Oct. 14-15 meeting.

Revised on February 23, 1998, based on fax/ccmail messages of January 6, 1998 and February 16, 1998 from J. Draxler.

Revised on May 4, 1998, based on meeting with Jim Draxler.